Properties of LNG - Hazards and History

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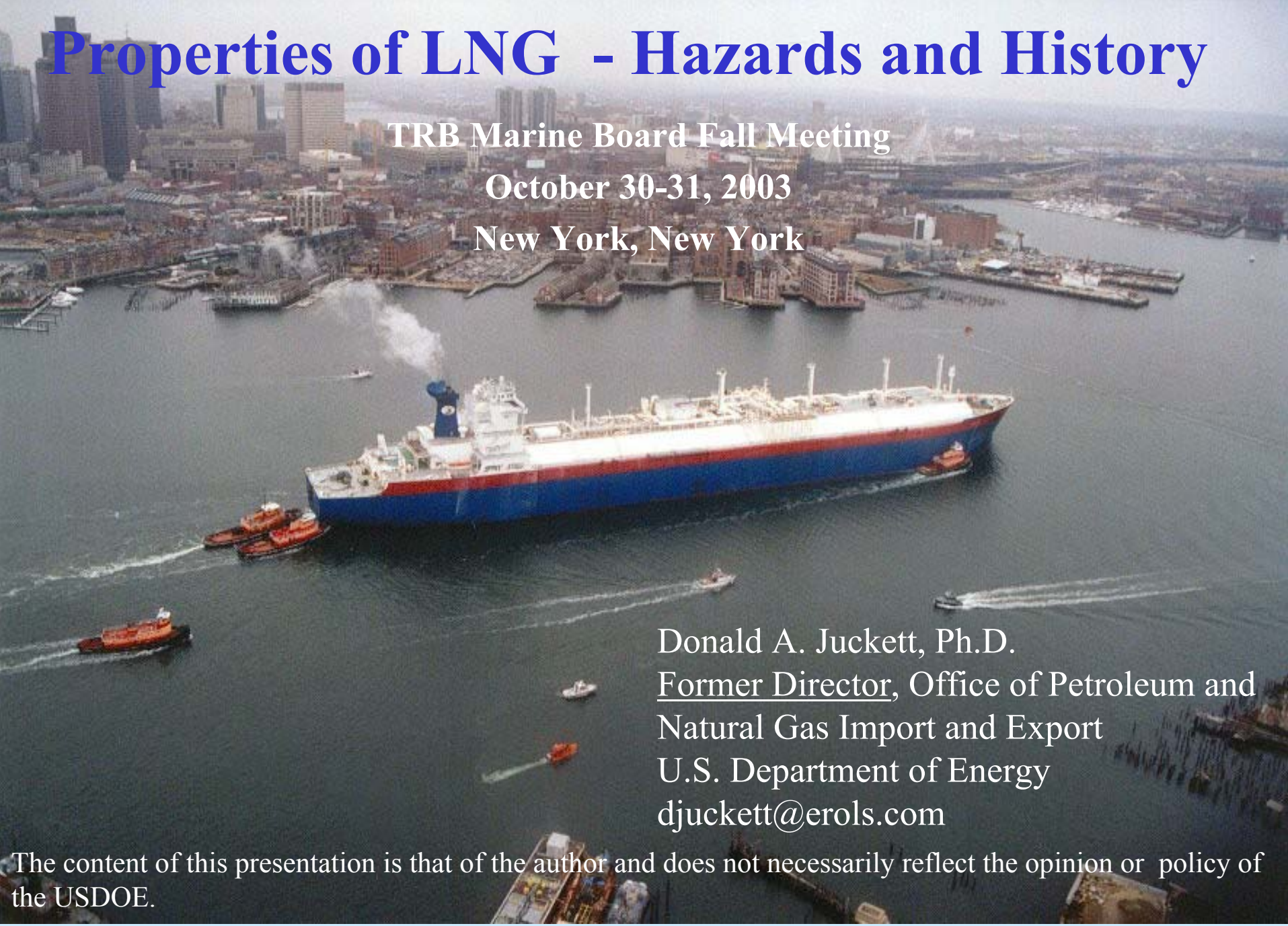

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LNG and Natural Gas

- **Physical properties and behavior**
- **Myth and Legend**
- **Knowledge and Common Sense**
- **Hazards -**

LNG Properties

- **Liquefied Natural Gas is a Cryogenic Liquid**
  - LNG Density - 26.5 LB./Cu. Ft.
    - Lighter than water (65 LB/Cu. Ft.)

- **Other Cryogenic Liquids in Context**
  - LNG Boiling point - (-259^{o} F)
    - Liquid Nitrogen - (-320^{o} F)
    - Liquid Oxygen - (-297^{o} F)

Natural Gas Properties

- **Natural gas is lighter than air**
  - Natural Gas Density - 0.47
    - (Air - 1.0)
- **Natural gas rises under normal atmospheric conditions**

Common Sense and Knowledge

- Natural gas needs to be in vapor form and mixed with air to burn.
- Natural gas is combustible in the range of 5% to 15% volume concentrations in air.
- Combustible mixtures in confined space will burn explosively
  - **LNG does not explode or burn**

Common Sense and Knowledge

- **LNG is a cryogenic liquid – physical contact or spillage constitute a personnel and equipment hazard**
- **LNG**  **Natural Gas**
- **Natural Gas presents an asphyxiation hazard**

Myth and Legend

- "Catastrophic release of LNG creates a BLEVE -- boiling liquid expanding vapor explosion"

–NOT TRUE

  - In laboratory and open ocean combustion tests, there have been ***no*** documented cases of LNG BLEVEs

What happens with a spill on water?

- LNG pool vaporizes rapidly (faster than an equal sized pool on land)
- LNG spill on or within hull can cause brittle fracture (carbon & low alloy steel)
- LNG can undergo “rapid phase transition”, a ***physical*** vapor explosion (not combustion)
- LNG pool formation accompanied by ignition
- Natural gas cloud formation with subsequent burn back

Assessing The Hazard
30 Years of LNG Experience

- LNG history in the US dates back to 1940's
- LNG tanker trade initiated with exports in 1969
- Eight marine incidents have resulted in spillage of LNG - some hull damage due to cold fracture and no cargo fires
- Seven incidents not involving spillage - two from grounding - no cargo loss
- LNG carriers are inherently much more robust than typical crude, fuel, and chemical tankers

Assessing The Hazard

- LNG vaporizes and causes condensation of atmospheric moisture – visible cloud
- As LNG vapor cloud warms it lifts
- Water is a superior heat source compared to soil/solids
- Spills on water tend to vaporize rapidly creating a potentially combustible plume that migrates until a) the LNG source is exhausted, and b)dilution by air reduces the concentration below the lower flammability limit (LFL)

Assessing The Hazard

- An ignition source close to the origin of the spill is likely to cause ignition and result in rapid burn off of natural gas vapors
- Absence of an ignition source would result in a plume that could migrate downwind for a considerable distance (3-6 KM).
- A remote (downwind) ignition of a plume in the flammable portion of the vapor cloud would result in relatively slow (subsonic) burn back to the spill pool

Summary of Conclusions from the Lloyd's Report

Report draws from many sources, historical, experimental, and modeling

- **Historically for all types of LNG - no loss of life - land based property damage - environmental damage**
- **LNG carriers inherent strength has prevented loss of containment**
- **A missile hit or explosion will provide a large number of ignition sources**
- **If containment loss should occur under specific conditions**
  - **Holing may not be visible**

Summary of Conclusions from the Lloyd's Report

- **There is potential for escalating failure due to embrittlement - with subsequent explosion/fire**
- **Ignition and sustained burn of a vaporized LNG cloud is difficult - multiple ignition sources would probably result in a burn back to the source**
- **Unconfined LNG vapor cloud detonation has not been demonstrated and unlikely**
- **External ignition (of vapor cloud) results in slow moving flame**
- **Rapid Phase Transition will not cause ignition but potentially damaging for ship/equipment**

Summary of Conclusions from the Lloyd's Report

In terms of pool spread

- **The LFL for methane/air mixtures is ~5% so the LFL boundary is well within the visible cloud**
- **Modeling of dispersion cloud 3-6 km. Dispersion on that scale unlikely because of local ignition sources**
- **Exposure at 300 meters (1000ft) from a pool fire would cause pain within 60 seconds**
- **Warming gas cloud will become lighter than air and rise**
- **No direct environmental damage or clean up from primary spill**
- **A fire fed by single (25,000 m^3) cargo tank vented through a 1m^2 hole would last 1hr - burn diameter 25 meters**

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